Acta Horticulturae. 2006. V. 706. Pp. 121-128.

QUALITY EVALUATION OF SOME CULTIVAR TYPES OF LEAFY *BRASSICA RAPA*

A.M. Artemyeva and A.E. Solovyeva
N. I. Vavilov Research Institute of Plant Industry, St-Petersburg, Russia

Keywords: Pak choi, Chinese cabbage, Mibuna, Mizuna, Komatsuna, Tatsoi, bioactive substances, ascorbic acid, carotenoids, chlorophylls, β-carotene, sugars, protein, glucosinolates, minerals

Abstract. The VIR collection of leafy *Brassica rapa* L. including 525 accessions of 5 crops was divided into 27 cultivar types. Biochemical composition of all crops and cultivar types has been investigated. Among the cultivar types the sources of nutritive and bioactive substances were revealed.

INTRODUCTION

Brassica crops rank third among the major vegetable botanical groups in production and consumption after potatoes and tomatoes in developed countries and second after grain crops in developing countries (Rosa 1999). In Russia *Brassicas* take third place after cereals and potatoes.

Worldwide distribution of *Brassica* vegetables is determined by many factors. Vegetable *Brassica* crops have diverse edible plant parts and various ways of utilization for human consumption: in fresh and as a processed food. After the harvest of the main product part the remaining biomass is used for fodder. *Brassica* vegetables are remarkable for high yield, ecological plasticity, and valuable biochemical composition.

Food nutrition is becoming one of the most important factors in the choice of products in modern conditions. *Brassica* vegetables are characterized by high water content, low caloric value, contains high quality protein, carbohydrates, fibre, vitamins, minerals, secondary plant metabolites. In humans, the last mentioned have anticarcinogenic, antioxidant, antibacterial and antiviral effects, stimulate the immune system and reduce inflammation. *Brassicas* also prevent from development of cardiovascular diseases and illnesses associated with ageing (King, Barker 2003).

These arguments enable to recommend increased consumption of *brassicas*.

The Russian *Brassica* collection maintaining at the Vavilov Institute of Plant Industry (VIR) consists of 6603 accessions, including 525 accessions of leafy *Brassica rapa*. Among the last 381 accessions of Chinese cabbage (*Brassica rapa* ssp. *pekinensis* (Lour.) Hanelt in Schultze-Motel), 100 accessions of pak-choi (*B. rapa* ssp. *chinensis* (L.) Hanelt in Schultze-Motel), 14 accessions of tatsoi (*B. rapa* ssp. *narinosa* (Bailey) Hanelt), 15 accessions of Mizuna and Mibuna (*B. rapa* ssp. *nipposinica* (Bailey) Hanelt in Schultze-Motel) and 15 accessions of leafy turnip (*B. rapa* ssp. *rapifera* (L.) Metzg.) are situated. The collection includes 28.8% landraces, 12.2% old cultivars, 17.6% advanced cultivars, 41.4% breeding materials. Earlier we have analyzed bioactive substances in the Brassica green vegetables (Artemyeva, Solovyeva 2003).

The leafy vegetable *Brassica rapa* are rich sources of nutritives and bioactive substances. They are characterized by high contents of proteins, carotenoids, chlorophylls, phenolic acids, flavonoids and sulfides. Due to the promoting effect of carotenoids and chlorophylls, the *Brassica rapa* has been investigated to determine the contents of the total carotenoids, the total carotenes and the main carotinoids – β-carotene and chlorophylls (a and b). Our studies of nutritive and bioactive substances have been

Table 1. Cultivar types of leafy *Brassica rapa*

Subspecies/varieties	Cultivar types	Subspecies	Cultivar types
***Pekinensis dissoluta* Li**	Dunganskaya	**chinensis**	Siyusman
	Mana		Piorbai
	Shirona		Taisai
	Hiroshimana		Yu tsai
***Pekinensis infarcta* Li**	Shantung	**narinosa**	Chrysanthemum
	Siao		Ta-gu-tsai
	Nagasaki	**nipposinica**	Mibuna
	Chirimen		Mizuna
***Pekinensis laxa* Tsen et Lee**	Chosen	**rapa**	
	Kashin		
***Pekinensis cephalata* Tsen et Lee**	Chee-Foo (Wong-Bok)		
	subtype Matsushima		
	Hotoren		
	Kaga		
	Aichi		
	subtype Nozaki		
	Granat (Michihli)		
	Da-zin-kou		

focused on genetic effects and evaluation of VIR collection of *Brassica rapa.*

MATERIALS AND METHODS

Material. For a within subspecies differentiation of leafy *B. rapa* accessions, morphological, environment and molecular biochemical approaches were used (table 1).

The genetic effect of the content of nutritive and bioactive substances has been investigated using 5 crops of *Brassica* rapa, grown in the field in Saint-Petersburg area during 3 years. The cultivars were represented by 28 samples pak-choi, 102 samples Chinese cabbage, 15 samples mibuna and mizuna, 14 samples leafy turnip and 9 samples tatsoi.

Analysis of Nutritives and Bioactive Substances. The cultivars were sown in the open field at the end June. The plants were harvested, when the plant or head diameter have reached its maximum, usually from July to the end of September. The samples were analyzed as the fresh material. For each cultivar, five plants were selected at random; a section was taken from each crop. These samples were processed and analyzed as previously described (Ermakov et.al. 1987).

The quantitative ascorbic acid was determined in direct plant extracts with 2,6-dichloroindophenol by visual titration. The total sugars were determined in direct plant water extracts by the Bertran method. The content of total proteins was estimated in dry material by the Kjeldahl method. The pigment concentrates we produced by acetone (70%) extraction. The carotinoids and chlorophylls were made by direct determination of the absorbency at different wavelengths, using a standard spectrophotometer (chlorophyll a – 663 nm, chlorophyll b – 645 nm, total carotinoids – 440 nm, β-carotene – 454 nm). The total carotenes were determined with using paper chromatography. For determination

Table 2. Genetic effects on the content of nutritive substances in leafy crops of *Brassica rapa*

Crop	Dry matter, %	Total sugars, % fm	Proteins, % dw
Pak-choi	6.18*	1.42	26.07
	2.84 – 14.76**	0.11 – 4.70	13.90 – 35.80
Chinese cabbage	5.84	1.09	12.93
	3.51 – 10.20	0.05 – 3.75	7.48 – 26.14
Mizuna, Mibuna	7.39	1.38	14.77
	4.88 – 12.02	0.11 – 3.10	10.12 – 19.08
Leafy turnip	7.93	1.60	-
	4.32 – 11.88	0.11 – 3.38	
Tatsoi	7.78	1.24	25.50
	2.80 – 12.56	0.15 – 3.46	13.00 – 38.00

* - average
** - ranges

of the total glucosinolates a modified method for estimation of d-glucose released by hydrolysis of enzyme was used.

RESULTS AND DISCUSSIONS

Genetic effects. In our studies significant differences between crops and cultivar types in the *B. rapa* on the concentration of bioactive substances were found. The knowledge of these differences may be useful for improving *Brassica* breeding. The content of dry matter, sugars and proteins is presented in Table 2 and the content of chlorophylls, carotenoids, carotenes, β-carotene and glucosinolates is given in Table 3.

Dry matter. The dry matter content changed significantly between *Brassica rapa* cultivars. A well-defined difference in the dry matter level was seen for Pak choi (to 14.76%).

Total sugars. There were large differences in sugars distribution among different cultivars of *Brassica rapa.* In these plants the levels of accumulated monosaccharides and sucrose were relatively low. Some Chinese cabbage accessions of cultivar types Matsushima, Kaga, Hotoren (var. *cephalata* f. *ovata*) contained the highest amount of sugars (more than 1.5%) and the same has been observed for cultivar type Sijusman (pak-choi) and the hybrids *chinensis* x *narinosa*.

Proteins. The Chinese cabbage accession of cultivar type Granat (var. *cephalata* f. *cylindrica*) showed the highest protein content (22.6% dm). Within other crops the highest protein content has been observed in cultivar type Sijusman (pak-choi) and the hybrids *chinensis* x *narinosa*.

Ascorbic acid. *Brassica* vegetables are the rich sources of ascorbic acid for human nutrition. *Brassicas* constitute an important source of vitamin C (ascorbic acid) having beneficial properties: prevention of infarcts, cancer, infection, and antioxidant power.

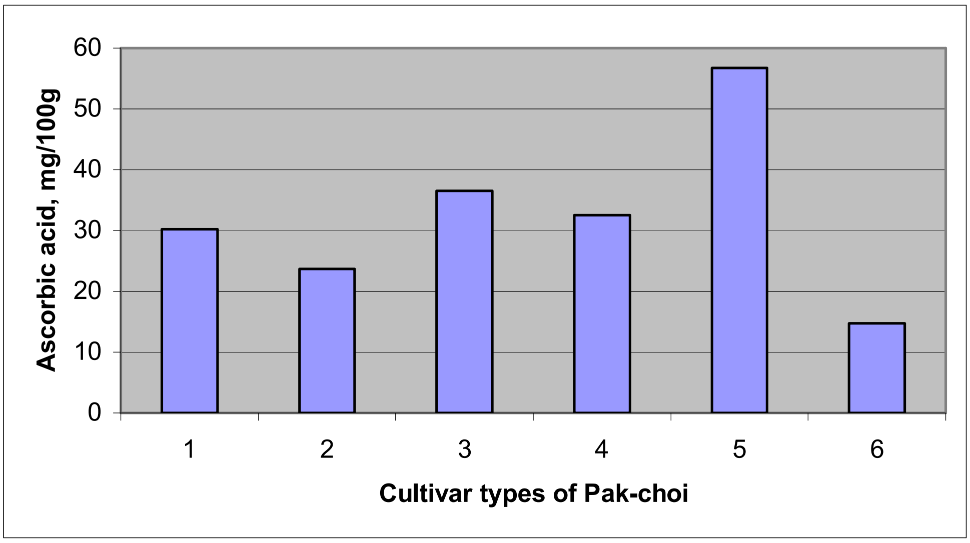

Fig.1. The content of ascorbic acid among 4 cultivar types of pak-choi and hybrids with pak-choi: 1 – Siyusman, 2 – Piorbai, 3 – Taisai, 4 – Yu Tsai, 5 – hybrids *chinensis* x *narinosa*, 6 – *chinensis* x *rapa*

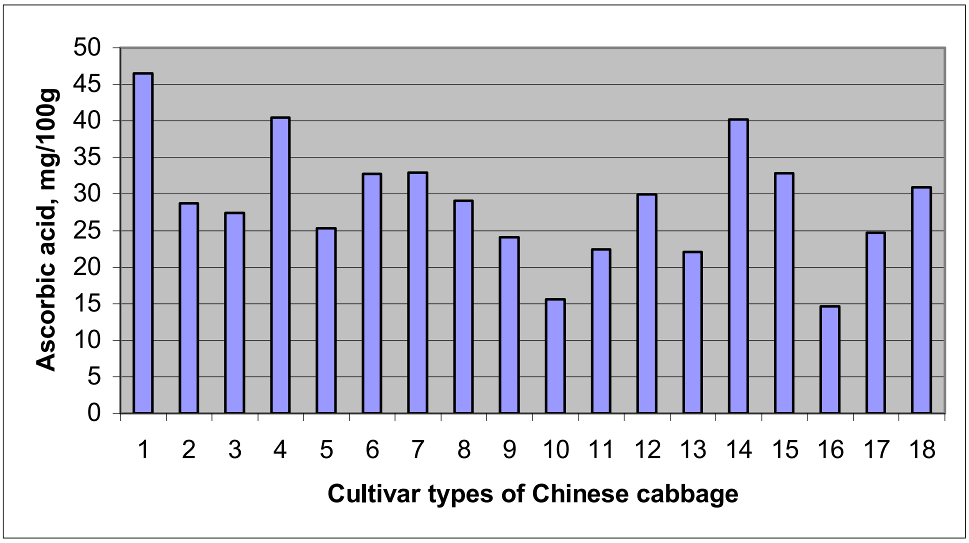

Fig.2. The content of ascorbic acid among 18 cultivar types of Chinese cabbage: 1 – Dunganskaya, 2 – Mana, 3 – Shirona, 4 – Hiroshimana, 5 – Shantung, 6 – Siao, 7 – Nagasaki, 8 – Chirimen, 9 – Chosen, 10 – Kashin, 11 – Chee-Foo (Wong-Bok), 12 – Matsushima, 13 – Hotoren, 14 – Kaga, 15 – Aichi, 16 – Nozaki, 17 – Granat (Canton, Michihli), 18 – Da-zin-kou.

Genetic variation for amount of ascorbic acid (AA) in *Brassica rapa* has been noted (table 3). The highest content of AA has been found in the following cultivars: Chinese cabbage – Dunganskaya, Hiroshimana, Kaga; pak-choi – Taisai and Ju-tsai; tatsoi – Ta-gu-tsai; leafy turnip, mibuna and also in natural and breeding hybrids between subspecies *chinensis* and *narinosa* (fig. 1, 2).

The adult daily norm of vitamin C is 60 μg RDA (Recommended Dietary Allowance). For example, Chinese cabbage contains on the average 22.5 mg of ascorbic

Table 3. Genetic effects on the content of bioactive substances in leafy crops of *Brassica rapa* (mg/100g fm)

Crop	Ascorbic acid	Chlorophylls A and B	Carotenoids	Total carotenes	β-carotene	Total glucosi-nolates
Pak-choi	33.86* 21.2-145.20**	115.50 64.22-236.25	20.96 4.71-38.41	7.45 3.6-15.54	4.84 2.96-10.18	4.72 1.24-11.80
Chinese cabbage	22.45 19.5-83.60	74.14 24.28-163.25	14.44 2.65-30.30	5.07 0.89-18.89	3.08 0.14-7.12	13.30 0.60-40.00
Mizuna, Mibuna	37.79 17.3-126.72	125.46 59.50-163.18	20.78 5.38-34.17	5.59 1.62-12.40	5.09 1.69-7.08	9.90 2.90-16.30
Leafy turnip	39.20 12.60-92.40	109.78 67.72-164.99	23.00 2.21-36.78	5.71 2.41-8.70	4.67 2.05-7.40	12.41 7.50-18.44
Tatsoi	41.59 15.7-124.08	114.80 74.98-231.37	22.90 15.78-29.38	7.58 3.25-15.30	4.66 3.00-6.38	9.57 2.60-25.78

* - average
** - ranges

acid per 100 g fm. Thus 100 g Chinese cabbage can supply 45% and but only 48 g Taisai and Ju-tsai (pak-choi) can supply 100% RDA.

Chlorophylls a and b. The chlorophylls occur universally as green pigments in all photosynthetic plant tissues. They can be found in the chloroplasts in relatively large amounts, often bound loosely to protein but are readily extracted into lipid solvents such as acetone or ether. Accumulation of chlorophylls in plants is determined genetically and allows to juge intensiveness of photosynthesis. For peoples and animals the chlorophylls play important role in dietary, since green leaves increase quantitaty of hemoglobin and eritrocites in blood.

Genetic variation has been found for amount of chlorophylls a and b in *Brassica rapa* crops. Total chlorophylls content ranges from 3 (Chinese cabbage) to 231 mg/100g (tatsoi) for *Brassica rapa.* The high content of total chlorophylls has been discover in tatsoi (max 231.37 mg/100g) and pak-choi (max 236.25 mg/100g). The cultivar types Ju-tsai (pak-choi), Chirimen, Nozaki, Granat (Chinese cabbage), Chrysanthemum and Ta-gu-tsai (tatsoi), Mibuna and Mizuna contained the highest amount of chlorophylls.

Carotenoids. Carotenoids, or C_{40} tetraterpenoids, are an extremely widely distributed group of lipid-soluble pigments, found in all kinds of plant. In plants, carotenoids have two principal functions: as accessory pigments in photosynthesis and as colouring matters in flowers and fruits. They frequently occur along with chlorophyll in all green plant tissue, and often leafy vegetables are good sources of carotenes, although in these plants the chlorophyll molecules mask the color of carotenes.

Along with total energy deficiency, vitamin A and protein deficiencies are estimated to be the most common dietary needs in the world. Epidemiological studies indicate that a higher intake of carotene or vitamin A may reduce the risk of cancer. Among the 500-600 distinct natural carotenoids identified so far, only 50 ones could be converted to vitamin A in the animal body, and among all of them *trans*-β-carotene has the greatest vitamin A

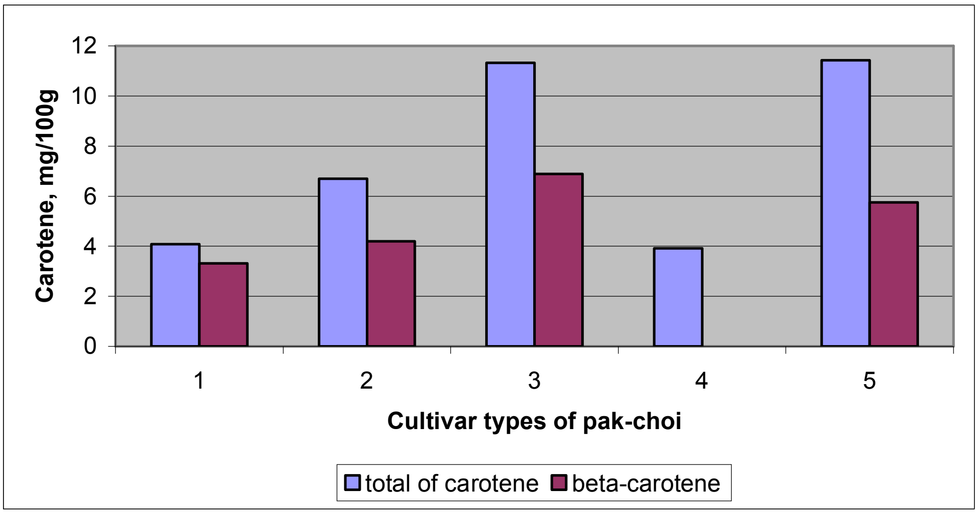

Fig.3. The content of carotene among 4 cultivar types of Pak-choi and hybrids with pak-choi: 1 – Siyusman, 2 – Taisai, 3 – Yu Tsai, 4 – hybrids *chinensis* x *narinosa*, 5 – hybrids *chinensis* x *rapa*

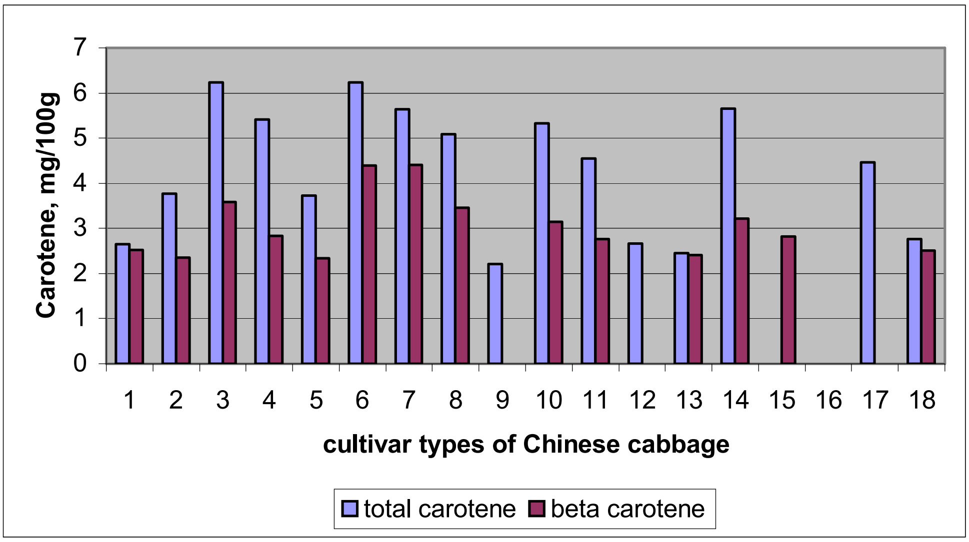

Fig.4. The content of carotene among 18 cultivar types of Chinese cabbage: 1 – Dunganskaya, 2 – Mana, 3 – Shirona, 4 – Hiroshimana, 5 – Shantung, 6 – Siao, 7 – Nagasaki, 8 – Chirimen, 9 – Chosen, 10 – Kashin, 11 – Chee-Foo (Wong-Bok), 12 – Matsushima, 13 – Hotoren, 14 – Kaga, 15 – Aichi, 16 – Nozaki, 17 – Granat (Ccanton, Michihli), 18 – Da-zin-kou.

activity. Genetic variation for amount of carotenoids in leafy *Brassica rapa* is presented in Table 3. The size of β-carotene fractions can achieve 76-98% of the total carotens.
The best sources of β-carotene (fig. 3, 4) are situated in the cultivar types Chirimen, Shirona, Siao, Hiroshimana, Nagasaki, Chirimen, Kashin (Chinese cabbage); Ju-tsai (pak-choi); Chrysanthemum (tatsoi) and mibuna.
Glucosinolates. This class of sulphur-containing glucosides is the most important among

the secondary plant metabolites. Sulphur compounds are partly responsible for the flavour of many vegetables, including *Brassica* crops. The pungency of cabbage, mustard, etc. depends largely upon the active breakdown products from glucosinolates (Fenwick et. al. 1983). These are produced by enzyme action on a precursor when the two are brought into contact, by damage of cells or membranes in the process of the tissue disruption (cutting, crushing, autolysis). The volatiles, which are responsible for the odour, are not even present in the intact tissue. The glucosinolates present in the cell normally as potassium salts which are colorless and water-soluble. High level of their derived compounds prevents from using *Brassica* biomass for fodder. The presence of glucosinolates limit insect and fungal attack in plants (Finch 1978, Rosa 1999), and same of the derivatives from glucosinolates are said to be potential goitrogens, particularly when the diet is deficient in iodine (Wills 1966). Physiologically active compounds (isothiocyanates) neutralise effect of chemical carcinogens (Fenwick et. al. 1983), possess antiproliferative activities and reduce rise of cancer.

Genetic variation has been found for amount of glucosinolates in leafy *Brassicas* (table 3). Low level of glucosinolates was showed by the plants of the following cultivar types: Sijusman (pak-choi); Shantung, Siao, Chirimen (semi-heading Chinese cabbage), Hiroshimana (leafy Chinese cabbage); Ta-gu-tsai (tatsoi), and mizuna. High level of glucosinolates has been noted for the cultivar types of Chinese cabbage: Kashin, Chosen (fluffy-toped heading), Nagasaki (semi-heading), Nozaki (heading) and Chrysanthemum (tatsoi).

Minerals. Most Brassicas are an excellent source of minerals, such as calcium and iron, and their availability for human nutrition is relatively high (table 4).

Our investigations show accumulation levels of antioxidant Se in plants pak-choi and Chinese cabbage, which consist 230.04±120.5 μg/kg dry weight for pak-choi (ranges from 122 to 383 μg/kg) and 216±93.83 μg/kg for Chinese cabbage (ranges from 82 to 308 μg/kg). Consequently, there are cultivars, which accumulate selen (in soil content of selen is 246 μg/kg).

Inter-cultivar variation of Na accumulation levels was determined from 420 to 8260 mg/kg, for concentration of K average 4.00 μg/kg. *Brassica rapa* is regarded as a good source of available calcium (average 1.27 mg/kg).

Due to high levels of Fe accumulation *Brassica rapa* is distinguished among other *Brassica* species. This is very important fact in relation to Fe deficit in the world and Russia. For receiving the adult daily norm of Fe man needs about 200g *Brassica rapa.*

Furthermore, we have shown that there is potential for differentiating between and within subspecies in the *Brassica rapa* species. All crops contain large quantity nutritive and bioactive substances. Highest content of the investigated bioactive substances found in pak-choi and tatsoi.

The Russian collection provides a potential source of genes and can be used in breeding programs. The information in this report should enable breeders to more effectively use their breeding program.

References

1. Artemyeva A.M., Solovyeva A.E. 2003. Bioactive substances in the Brassica green vegetables. Report of Vegetable meeting. Poland (in press).
2. Ermakov A. I., Arasimovich V. V., Yarosh N. P., et.al. 1987. Methods of biochemical research into plants (A. I. Ermakov, ed.). Leningrad: Agropromizdat, Russia.

3. Fenwick G. R., Heaney R. K., and Mullin W. J. 1983. Glucosinolates and their breakdown products in food and food plants. C. R. C. Critical Rev. Food Science & Nutrition, 18: 123.
4. Finch S. 1978. Volatile plant chemicals and their effect on host plant finding by the cabbage root fly. Ent. Exp. Appl. 24: 350
5. King G., Barker G. Health. 2003. Medical and Clinical benefits of Brassica consumption. HRI – Wellesbourne. Nov. www.brassica.info
6. Rosa E.A.S. 1999. Chemical composition. Biology of Brassica coenospecies. Amsterdam – Lausanne – New York – Oxford – Shannon – Singapore – Tokyo. Pp. 315-357.
7. Temichev A.V. Selecting of *Brassica rapa* initial forms for breeding on quality of production in Nonchernozem zone of Russia. - Ph.D.Thesis, Moscow, 2004, 24 p. (in Russian)
8. Wills J. H. 1966. Goitrogens in foods. Pp. 1354 *in* Toxicants Occurring Naturally in Foods, National Academy of Sciences, National Research Council, Washington, D. C., USA

Table 4. The content of minerals in leafy crops of *Brassica rapa* (mg/kg dm)
(Temichev A.V., 2004)

Cultivar type	**Na**	**K, µg/kg**	**Ca**	**Se**	**Cr**	**Mn**	**Fe**	**Co**	**Ni**	**Zn**	**As**	**Se, µg/kg**	**Br**	**Rb**	**Cd**	**Sb**	**La**	**Ce**	**Hg**	**Au**	**Th**	**Pb**
Chinese cabbage																						
Shantung	2070	7.46	1.76	0.17	1.9	68	460	360	2.9	35	0.09	198.0	25	19	0.6	0.09	1.5	2.5	<0.05	0.002	0.19	1.9
Matsushima	610	2.39	1.03	0.09	1.0	34	290	110	2.1	27	0.05	169.0	11	5	0.2	0.02	0.7	1.2	<0.05	0.004	0.06	<0.5
Chosen	1280	3.32	1.50	0.21	1.7	66	600	350	4.0	36	<0.05	245.8	15	14	0.4	0.04	1.6	2.9	0.09	0.01	0.28	0.5
Mana	480	4.04	1.28	0.08	1.0	17	820	130	<0.5	33	<0.05	138.0	18	5	0.2	0.02	0.4	0.7	<0.05	0.022	0.07	<0.5
Kaga	500	2.58	1.48	0.35	2.5	50	940	360	2.3	28	0.13	260.0	12	7	0.4	0.03	1.5	3.7	<0.05	0.012	0.31	0.8
Siao	1220	5.07	1.35	0.05	0.9	42	240	120	2.1	23	0.06	247.0	36	12	0.5	0.14	0.8	1.2	0.05	0.003	0.18	<0.5
Pak-choi																						
Piorbai	420	2.85	0.93	0.19	2.1	37	590	300	1.1	37	0.15	182.0	12	3	0.7	0.03	1.0	1.4	<0.05	0.011	0.17	<0.5
Taisai	1170	3.35	1.36	0.21	1.1	44	610	340	4.4	36	0.09	227.0	15	12	0.5	0.05	1.5	2.7	0.07	0.012	0.19	0.5
Siyusman	8260	5.41	0.91	0.07	0.9	28	220	190	3.3	36	0.05	250.7	25	25	0.6	0.08	0.8	1.3	<0.05	0.007	0.06	<0.5
Tatsoi																						
Chrysanthemum	845	3.54	1.11	0.15	1.6	55	530	440	4.5	72	<0.05	256.0	10	20	0.3	0.07	1.8	2.7	<0.05	0.002	0.18	0.6